# SOILS 2015

# SOIL SCIENCE CONFERENCE OF MALAYSIA

## SOIL SECURITY FOR SUSTAINABLE FOOD PRODUCTION

2015 International Year of Soils

**APRIL 7 - 9, 2015**
**THE EVERLY HOTEL, PUTRAJAYA**

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# PROCEEDINGS

Jointly Organized

PERSATUAN SAINS TANAH MALAYSIA · MALAYSIAN SOCIETY OF SOIL SCIENCE

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# CAN WE BUILD AGRICULTURE MODELS IN EXCEL?

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## INTRODUCTION

Most agriculturists receive no to very little formal training in computer programming. Consequently, they often struggle to translate their agriculture models into computer programs that can be correctly understood and executed by a computer. For them, computer programming often becomes a tedious and time-consuming drudgery that distracts them from their main purpose of study or work.

This paper describes *BuildIt*, an Excel add-in that works within Microsoft Excel to enable the implementation of simple to large, complex models in Excel (Teh, 2011). Spreadsheets like Excel provide a modeling platform that requires the least proficiency in computer programming. Unlike other modeling platforms that enforce a rigid programming structure, spreadsheets' unrestricted and open structure enable novices and non-programmers to easily implement their models in a spreadsheet and to have the spreadsheet run the model simulations.

Nonetheless, Excel does have several key limitations that prevent the implementation of large, complex models. To circumvent these limitations, Excel's programming language, VBA (Visual Basic for Applications), could of course be used. However, using VBA requires programming skills in which most agriculturists lack. Moreover, requiring agriculturists to learn VBA would defeat the purpose of having an alternative and easier way for agriculturists to implement their models.

To overcome Excel's limitations, an Excel add-in, called BuildIt, was developed. Although BuildIt was developed using VBA, BuildIt shields users from VBA. With BuildIt, users are able to implement simple to complex models in Excel without requiring knowledge in VBA or a strong proficiency in computer programming.BuildIt removes—or at least, greatly reduces—the distraction of computer programming and allows agriculturists to concentrate on the more important task of building their mathematical models and using them in their studies or work.

## MATERIALS AND METHODS

BuildIt overcomes some of Excel's weaknesses mainly by providing: 1) a loop for iterative calculations and 2) *actions* to perform certain specific tasks not possible or difficult to do in native Excel. A loop needs to be setup if a model requires the same set of calculations to be repeatedly performed. BuildIt requires three key information about the loop, which are: the loop counter, the interval size, and the loop criteria. The loop counter keeps track of the current loop cycle, the interval size is how much the loop counter should be incremented at the end of every loop cycle, and the loop criteria the condition to which to end the loop. BuildIt supplies 12 so-called actions, where each of these actions performs a specific task.

Users will typically adhere the following general steps in building their models in Excel:1) implement all model calculations, 2) set up a loop for the repetitive calculations, 3) set up additional tasks needed such as numerical integrations, initialization of variables, and solving differential equations, as well as copying and manipulation of cell ranges, 4) set up the model output; that is, to specify what to output from the model and where the model output should appear in the worksheet, and finally 5) run the model.

As an example, a generic crop growth model, called *gcg* (Teh, 2015, 2006), was built to demonstrate the use of Excel (with the support from BuildIt) to build such mathematical models. However, due to the size of this model, only excerpts of this model are shown in this paper.

## RESULTS AND DISCUSSION

The gcg model consists of five core model components: Meteorology, Photosynthesis, Energy balance, Soil water, and Crop growth development.

Figure 1 shows a portion of the calculations in the worksheet. Fig. 2 shows the loop information required from BuildIt. This section instructs BuildIt to run daily simulations until the crop growth reaches the flowering stage. The simulation date is Jan. 1, 2000. Fig 3. shows the output section which instructs BuildIt to output the crop growth stage, the various plant part dry weights, plant height, rooting depth, leaf area index, and rooting zone water content. Fig. 4 shows the output with charts drawn based on the model output in Fig. 5.

| | F | G | H |
|---|---|---|---|
| 9 | | **RESPIRATION** | |
| 10 | | n1 | =RM*2^((Tmean-25)/10)*WGL/(WGL+WDL) |
| 11 | | $R'_M$ | =MIN(dayassim_c,H10) |
| 12 | | $\Lambda'_{canopy} - R'_M$ | =dayassim_c-RM_c |
| 13 | | $(\Lambda'_{canopy} - R'_M) / G_T$ | =IF(GT>0,H12/GT,0) |
| 14 | | | |
| 15 | | **LEAF DEATH** | |
| 16 | | $(2-\xi_s)$ | =2-dvs |
| 17 | | n2 | 0 |
| 18 | | n3 | =dvr/H16 |
| 19 | | n4 | =dvr/0.1 |
| 20 | | $\varepsilon_{age}$ | =IF(H16>=1,H17,IF(H16<=0.1,H19,H18)) |
| 21 | | n5 | 0 |
| 22 | | n6 | =0.03*MIN(1,(L-Lmax)/Lmax) |
| 23 | | $\varepsilon_{sh}$ | =IF(L<=Lmax,H21,H22) |
| 24 | | $\varepsilon_L$ | =MAX(eage,esh) |
| 25 | | | |
| 26 | | **LEAF AREA** | |
| 27 | | SLA | =interpolate(frac_dvs,frac_SLA,dvs) |
| 28 | | L | =WGL*SLA |

Figure 1: Excel worksheet showing a small excerpt of the calculations in the gcg model. Equations are implemented using Excel formulas and functions.

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **INPUT** | | | | | |
| 2 | date | =DATE(2000,1,1) | | current date | =B2+INT(_step) | |
| 3 | | | | doy | =date-DATE(YEAR(date),1,0) | |
| 4 | **CONTROL** | | | hour | | |
| 5 | | | | | | |
| 6 | stepsize | 1 | | | | |
| 7 | step | | | | | |
| 8 | criteria | =dvs<=2 | | | | |
| 9 | | | | | | |

Figure 2: Excel worksheet showing the loop information. This section instructs BuildIt to start crop growth simulations starting from Jan. 1, 2000 and to run the simulation until crop growth reaches stage 2 or the flowering stage (harvest).

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **TO OUTPUT** | | | | | | | | | | | |
| 2 | **days** | $\xi_s$ | $W_{GL}$ | $W_{DL}$ | $W_S$ | $W_R$ | $W_O$ | h | $d_{root}$ | L | $\Theta_{v,root}$ | |
| 3 | =date-Control!B2 | =dvs | =WGL | =WDL | =WS | =WR | =WO | =h | =droot | =L | =Water!E12 | |
| 4 | | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | **OUTPUT** | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |

Figure 3: Excel worksheet showing the list of parameters to be included in the model output: the growth development stage ($\xi_s$), the dry weights for green leaves ($W_{GL}$), dead leaves ($W_{DL}$), stem ($W_S$), roots ($W_R$), and storage organs ($W_O$), plant height (h), rooting depth ($d_{root}$), leaf area index (L), and the rooting zone soil water content ($\Theta_{v,root}$).

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **TO OUTPUT** | | | | | | | | | | | |
| 2 | **days** | $\xi_s$ | $W_{GL}$ | $W_{DL}$ | $W_S$ | $W_R$ | $W_O$ | h | $d_{root}$ | L | $\Theta_{v,root}$ | |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0.6 | 0 | 0.01 | |
| 4 | | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | FALSE | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | **OUTPUT** | | | | | | | | | | | |
| 8 | 0 | 0.1 | 1.44 | 0 | 0.29 | 0.16 | 0 | 0.04 | 0.04 | 0.04896 | 0.2 | |
| 9 | 1 | 0.125 | 1.864 | 0 | 0.397 | 0.222 | 0 | 0.049 | 0.052 | 0.06293 | 0.254 | |
| 10 | 2 | 0.149 | 2.31 | 0 | 0.515 | 0.291 | 0 | 0.059 | 0.064 | 0.07742 | 0.272 | |
| 11 | 3 | 0.173 | 2.94 | 0 | 0.692 | 0.393 | 0 | 0.07 | 0.076 | 0.0978 | 0.284 | |
| 12 | 4 | 0.197 | 3.588 | 0 | 0.884 | 0.503 | 0 | 0.084 | 0.088 | 0.11849 | 0.267 | |
| 13 | 5 | 0.221 | 4.406 | 0 | 1.139 | 0.649 | 0 | 0.098 | 0.1 | 0.14401 | 0.29 | |
| 73 | 65 | 1.793 | 54.45 | 172.9 | 264 | 68.69 | 136.1 | 0.4 | 0.496 | 0.6908 | 0.269 | |
| 74 | 66 | 1.823 | 46.98 | 180.8 | 264.8 | 68.94 | 141.8 | 0.4 | 0.496 | 0.57786 | 0.262 | |
| 75 | 67 | 1.854 | 39.18 | 188.9 | 265.4 | 69.14 | 147.2 | 0.4 | 0.496 | 0.46637 | 0.256 | |
| 76 | 68 | 1.883 | 31.48 | 196.8 | 265.8 | 69.28 | 152.1 | 0.4 | 0.496 | 0.36256 | 0.25 | |
| 77 | 69 | 1.913 | 23.55 | 204.9 | 266.1 | 69.37 | 155.9 | 0.4 | 0.496 | 0.26207 | 0.245 | |
| 78 | 70 | 1.943 | 16.61 | 211.9 | 266.2 | 69.41 | 158.7 | 0.4 | 0.496 | 0.17842 | 0.3 | |
| 79 | 71 | 1.973 | 11.71 | 216.8 | 266.3 | 69.43 | 161.1 | 0.4 | 0.496 | 0.12122 | 0.282 | |
| 80 | | | | | | | | | | | | |

Figure 4 : The model output which starts from row 8 until 72.

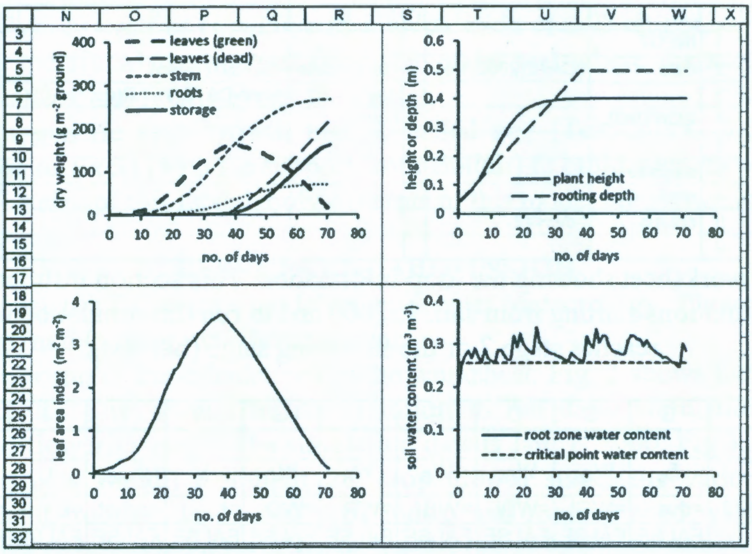


Figure 5: Charts are drawn from the model output to show the change in selected growth parameters and the soil water content. The model output shows that crop reached maturity and flowering growth stages in 35 and 71 days, respectively. The crop reached a maximum leaf area index of 3.7 $m^2$ leaf $m^{-2}$ ground at maturity growth stage, after which it declined in a near linear manner. The maximum dry weight for green leaves was 163 g leaf $m^{-2}$ ground. The maximum plant height achieved was 0.4 m and rooting depth was 0.5 m in approximately 30 and 40 days, respectively. Due to heavy and frequent rains, the crop very rarely suffered any water stress. The total soil water content was almost always above the critical soil water level, a level below which the crop's growth would be reduced due to the effects of water stress.

## CONCLUSIONS

BuildIt overcomes some limitations of Excel, enabling mathematical models to be easily implemented in Excel without requiring agriculturists to learn a computer programming language or be proficient in computer programming. With BuildIt, agriculturists can focus more on their modeling work and be distracted less by computer coding.

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